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Methyl Ester Preparation from Peanut Oil and Its Effect on DI Diesel Engine Combustion

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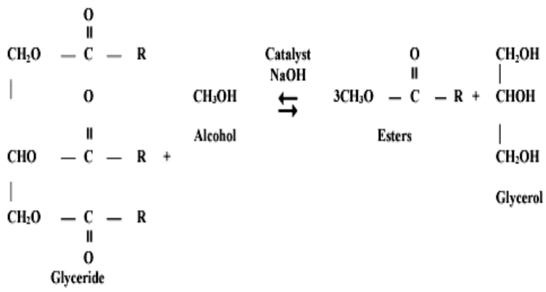
ABSTRACT

This study investigated the preparation of methyl ester (Biodiesel) from peanut oil by transesterification method and its effect on DI diesel engine. Two parameters were measured during the engine operation: one is engine performance (brake thermal efficiency and brake specific fuel consumption), and the other is the exhaust emissions (NOx and CO). The result showed that, when compared with neat diesel fuel, the brake thermal efficiency of biodiesel blend was almost similar or a slight lower. However, brake specific fuel consumption (bsfc) was a little higher than neat diesel. CO was lower and NOx was little higher with biodiesel blend than that of diesel. The engine performance for B10 and B20 was very similar. At medium and high load conditions the engine emissions for B10 and B20 has no significant variation. Hence, B20 can safely be used in diesel engine without any significant penalty in engine performance and emissions.

Keywords: DI diesel engine, performance and emissions, alternative fuel, biodiesel.

1. Introduction

The growing concern on industrialization and motorization of the world has led to sharp rise for the petroleum fuels. Petroleum based fuels are obtained from limited reserves. These finite reserves are not available all over the world. Those countries not having these resources facing energy/foreign exchange crisis due to import of crude petroleum. Hence, it is necessary to search for alternative fuels which can be produced from resources available locally. Among various options, methyl ester (biodiesel) has been reported to be one of the alternative fuels for reduction of this energy crisis [1, 2]. It is chemically known as "the mono alkyl fatty acid ester. Biodiesel can be produced from vegetable oils, waste frying oils, and animal fats etc. Vegetable oils have higher viscosity, low volatility and cold flow properties that cause injector cocking, piston ring sticking, fuel pumping problem and deposit on engine [3, 5]. These problems limit the direct use of vegetable oil in engine in place of conventional diesel. However, the limitations can be greatly minimized by converting the vegetable oil into ester through esterification. The transesterification reaction represented by the following equation-



Biodiesel can either be blended in any proportion with mineral diesel to create a biodiesel blend or be used in its pure form. It is an oxygenated, non-toxic, sulphur-free and biodegradable [6, 7]. Several countries have already begun substituting the conventional diesel by a certain amount of biodiesel [8]. The use of biodiesel is being promoted by EU countries to partly replace petroleum diesel fuel consumption in order to reduce greenhouse effect and dependency on foreign oil. Meeting the targets established by the European Parliament for 2010 and 2020 would lead to a biofuel market share of 5.75% and 10%, respectively [9].

Many investigations have shown that using biodiesel in diesel engines can reduce hydrocarbon (HC), CO and particulate matter (PM) emissions but NOx emission may increase [10, 11]. The increase in NOx emission can be avoided through modifying the properties of the biodiesel [12]. Engine parameters have significant effect on performance and emissions of diesel engine when run with biodiesel and its blend with diesel. Hence, a study was undertaken at RUET, Bangladesh to gather information on behavior of diesel engine when operated with biodiesel and its blend with diesel at varying engine parameters.

2. Objectives

The following are the main objectives of this work.

1. Preparation of biodiesel from peanut oil by transesterification method.

2. Optimization of different parameters for maximum biodiesel production.

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3. Determination of properties of diesel and different diesel biodiesel blends.

4. Performance and emissions study of a diesel engine with diesel and diesel-biodiesel blends.

3. Experimental setup and Measurement

A four-stroke single cylinder naturally aspirated DI diesel engine with specifications as in Table 1 was used in this experiment. All experimental data were taken after engine warm-up. The diesel fuel used in this study was available in the local market. The engine was mechanically loaded. At first the engine was run with moderate loaded and varying rpm for fixing the rpm at which the efficiency is maximum and used for all engine operation.

Table 1: Engine specifications

Engine type	4-stroke DI diesel engine
Number of cylinders	One
Bore x Stroke	95 x 115 mm
Compression ratio	20
Rated speed	1800 rpm
Average effective pressure	669kpa
Fuel injection timing	24^0 BTDC

The volumetric of blending ratio of biodiesel to diesel fuel was set at 10%, 20%. The rpm was measured directly from the tachometer attached with the dynamometer and indicator. Corresponding to each data point, exhaust emissions and fuel consumption were measured for diesel and biodiesel blends. A flue gas analyzer (IMR 1400) was used to measure CO and NOx of exhaust gases. Each data were taken repeatedly to get reasonable value.

4. Parameter optimization

4.1 Effect of methanol percentage on biodiesel production

Effect of methanol (CH_3OH) percentages on biodiesel production shown in Fig. 1. By keeping the weight percentage of sodium hydroxide (NaOH) constant at 0.50 [13]-[14], the percentage of methanol was varied from 15 to 25. The temperature was taken below the boiling point of alcohol. It can be seen from the figure, biodiesel production increases up to 20% of methanol and then decreases for all methanol percentages. This is due to the ratio of alcohol to vegetable oil interferes in the separation of glycerol. Lower the ratio required more reaction time. Higher the ratio more than 20%, conversion increased but recovery decreased due to poor separation of glycerol.

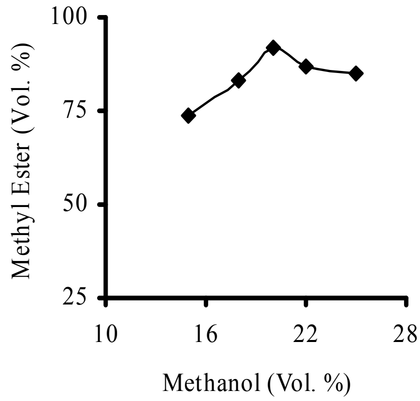

Fig. 1 Variation of biodiesel with methanol percentage. (NaOH 0.5%, Temperature 50^0C)

4.2 Effect of catalyst percentage on biodiesel production

Variation of biodiesel production with NaOH is shown in Fig. 2. The weight percentage of NaOH was varied from 0.45 to 0.75 [12]-[13]. Methanol was kept constant at 20%, which was optimized in Fig 1.

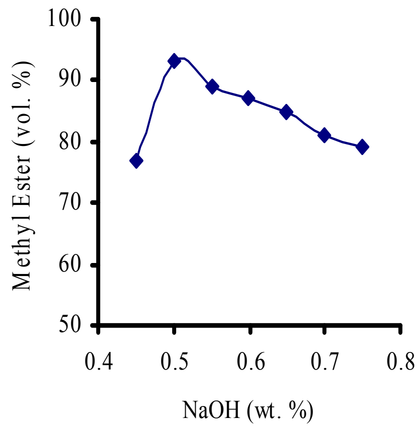

Fig. 2 Variation of biodiesel with NaOH percentage. (CH_3OH 20%, Temperature 50^0C)

From the figure it is seen that, biodiesel production increases up to 0.5% of catalyst and then decreases for all methanol percentages. This is due to vegetable oil contains many free fatty acid. The catalyst reacts with these free fatty acids and produces wax causes recovery decreases [14].

4.3. Effect of temperature on biodiesel production

The effect of temperature on biodiesel production is shown in Fig. 3. The temperature was varied from 35 to 58^{0}C. Here the volume percentage of methanol and catalyst was kept constant as 20% and 0.5% respectively which was optimized earlier.

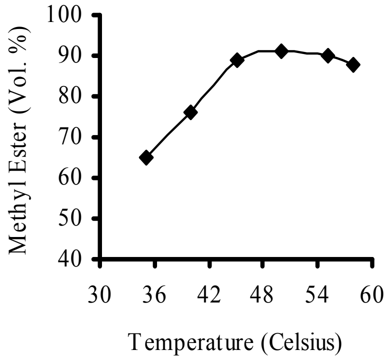

Fig. 3 Variation of biodiesel with temperature. (NaOH 0.5%, CH_3OH 20%)

It can be seen from the figure, biodiesel production increases up to 50^{0}C of reaction temperature and then decreases for further reaction temperature. Hence, the optimum condition for maximum biodiesel from peanut oil was 20% methanol, 0.5% NaOH, 50ºC reaction temperature and the maximum biodiesel production was 93 % by volume.

5. Experimental Results and Discussion

5.1 Comparison of different parameters among Diesel, Biodiesel and peanut oil

Table 2 Comparison of different parameters of diesel, biodiesel and peanut oil

Properties	Neat diesel	Peanut oil	B100	B10	B20
Density (gm/cc)	0.86	0.9	0.88	0.865	0.87
Viscosity (c.st) @ 30ºC	4.5	9.04	6.3	5.45	5.58
Higher heating value (kJ/kg)	44579	36500	39880	45895	45186
Flash point (ºC)	74	235	140	76	80
Fire point (ºC)	84	260	155	88	93

Table 2 illustrates the comparison of different parameters among diesel, biodiesel and peanut oil. The density, viscosity and higher heating value of biodiesel were found closer to diesel. The flash point, fire point was higher than the diesel, however, similar with other biodiesel.

5.2 Effect of BMEP on thermal efficiency

Effect of BMEP on thermal efficiency shown in Fig. 4. From the figure it is seen that, the efficiency trend increases with increase of BMEP for all the fuel. The efficiency trend is similar for all tested fuel at low BMEP conditions. At higher

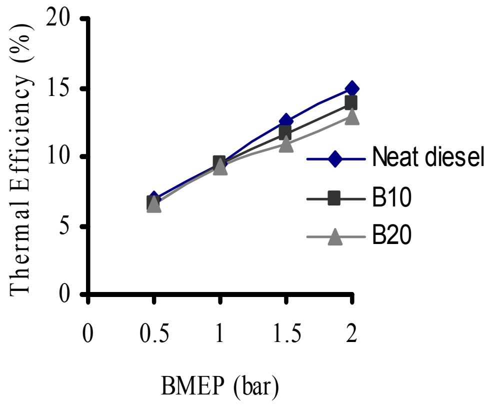

Fig. 4 Effect of BMEP on thermal efficiency. (at 1200 rpm)

BMEP the efficiency of B10 and B20 is lower than neat diesel about 7.6 % and 12.5% respectively. This is because of higher the load, higher the fuel consumption causes improper combustion in the absence of sufficient air responsible for efficiency decreases. The efficiency of biodiesel is lower than that of neat diesel due to lower calorific value of biodiesel.

5.3 Effect of BMEP on bsfc

The variation of bsfc with engine BMEP at 1200rpm shown in Fig. 5. From the figure it is seen that, bsfc decreases with BMEP for all tested fuel. B10 and B20 showed higher bsfc than that of neat diesel. At medium load conditions bsfc is very similar for all tested fuel. The bsfc of B10 and B20 is higher than neat diesel about 9.5% and 10% respectively. This is due to higher density and viscosity and lower calorific value of biodiesel.

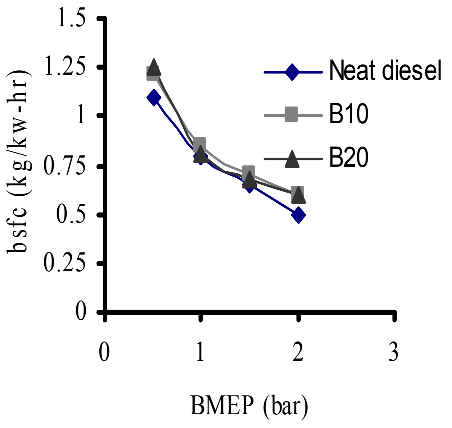

Fig. 5 Effect of BMEP on bsfc. (at 1200 rpm)

5.4 Effect of BMEP on CO emission

Fig. 6 shows the variation of CO at different engine BMEP with neat diesel and diesel-biodiesel blend.

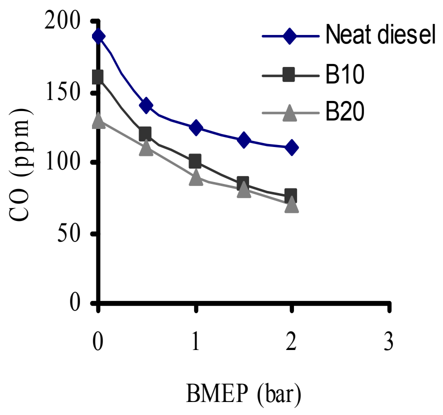

Fig. 6 Effect of BMEP on CO emission. (at 1200 rpm)

It is seen that, at low load conditions CO emission higher for all the fuel. But further increase of BMEP the CO emission decreased. The CO is lower for B10 and B20 fuel than that of neat diesel about 20% and 25% respectively. This is due to the better combustion of fuel facilitate by extra oxygen content of biodiesel.

5.5 Effect of BMEP on NOx emission

Fig. 7 shows the variation of NOx emission with various engine BMEP for neat diesel and biodiesel blend. From the figure it is seen that, at low load condition, NOx emission is higher with all tested fuel. NOx emission increased when the BMEP is increased. At medium load conditions, the NOx emission of B10 and B20 closer to neat diesel fuel. Since, biodiesel contain extra oxygen which ensures better combustion of fuel and high cylinder temperature. Hence, at high combustion temperature this oxygen reacts with nitrogen and causes excessive NOx emission.

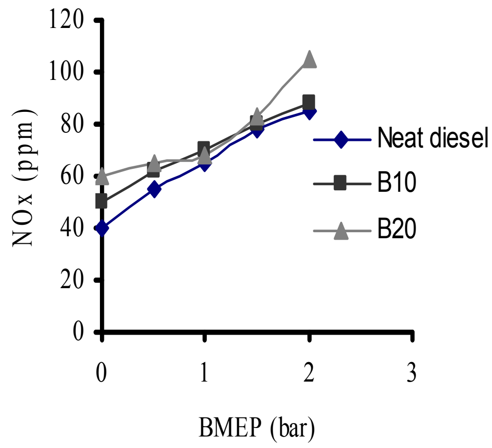

Fig. 7 Effect of BMEP on NOx emission. (at 1200 rpm)

6. Conclusions

The following conclusions can be drawn from the experimental investigation:

1. Biodiesel was prepared from peanut oil by transesterification process.

2. Maximum 93% biodiesel production was found at 20% methanol and 0.5% NaOH at 50^0C reaction temperature.

4. The viscosity, density for biodiesel is higher than those of diesel fuel. The heating value of biodiesel is lower than the diesel fuel.

3. Compared with conventional diesel fuel, diesel exhaust emissions including CO were reduced .While NOx emission was increased with biodiesel blends due to excess oxygen content in the fuel.

4. Thermal efficiency with diesel biodiesel blended fuel is slightly lower than that of conventional diesel fuel.

5. Since, The engine performance for B10 and B20 was very similar and at medium and high load conditions the engine emissions for B10 and B20 has no significant variation. So, B20 can safely be used in diesel engine without any significant penalty in engine performance and emissions and can be replace the conventional diesel fuel.

NOMENCLATURE

BMEP: Brake Mean Effective Pressure, bar
bsfc : Brake Specific Fuel Consumption, kg/kw-hr
B20 : 20% biodiesel and 70% diesel
B10 : 10% biodiesel and 90% diesel
CO : Carbon monoxide
c.st : Centistokes
DI : Direct Injection
NaOH: Sodium hydroxide
^{0}C : Degree Celsius

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